STUDY OF A MARTIAN AEOLIAN SAND ANALOG WITH MECA MICROSCOPY

J. Marshall[1], K. Kuhlman[2], R. Stevens[3], M. Meyyappan[3]. (1) SETI Institute, NASA Ames Res. Ctr., MS 239-12, Moffett Field, CA 94035; jmarshall@mail.arc.nasa.gov, (2) Jet Propulsion Lab, Pasadena, CA, (3) NASA Ames Res. Ctr., Moffett Field, CA.

If the Mars '01 mission had not been aborted, there would be the prospect of returning the first microscope images of surface materials in about a year from now. The experiment already fully fabricated for this microscopy task was the Mars Environmental Compatibility Assessment (MECA) which combined optical and atomic force microscopy, wet chemistry, electrometry, and various other analytical capabilities. Here we illustrate the type of data that might be returned in the future should another flight opportunity arise. To demonstrate scientific and technical merits of microscopy on Mars, we analyzed a possible Martian analog --a red dune sand from central Australia (from near Mt. Olga). Material herein is a rudimentary beginning to developing a database for future images returned from Mars.

In companion abstracts [1], other instrument concepts are described that we believe should also be considered for *in situ* deployment on Mars; LEAP molecular analysis, interferometry, and EDAX. These instruments have yet to be miniaturized for flight; work is currently underway to achieve this. Their analytical capabilities complement the type of data from MECA. The same aeolian sand analog is analyzed by some of these instruments for comparison with data presented in this abstract.

Here, and in [1], we also attempt to understand the micro/nano-scale origin of the red coating on the sand, and the process by which the coating becomes ubiquitous on grain surfaces. Mars has a pervasive brownish-yellow coloring, and it is important to know if this surface "staining" reflects predominance of a mineral of this particular color, or if coloration is the result of surface coatings on grains. Materials in arid areas are prone to coatings and layers such as desert varnish, caliche, and the mineral staining on aeolian sand.

Figure 1 shows the aeolian grains in one of the "microbeakers" (3-mm diameter cavities) on the MECA microscope stage. At this scale, it is possible to determine that grains are predominantly subangular to subrounded with patches of red staining on the surfaces. Transparency of the grains is also apparent. Although we know *a priori* that this is dune sand, it is not possible at this magnification to differentiate between aeolian and water transport. But it is possible to determine that transport modification is very immature compared to the degree of rounding achievable in fluid transport environments.

To calibrate these observations, higher optical magnifications were employed (higher than available to MECA). They showed the predominant grain mineral to be quartz, and that grain surfaces have a qualitatively assessed coverage of 10-50% of a red coating mainly residing in surface concavities.

We note that this limited surface coverage gives individual grains only moderate coloration. Yet, the sample in bulk appears very deep red as if to suggest a much higher concentration of the coating material. Thus, color can be deceptive for assessing sample composition; several layers of transparent grains transmit color to the sample's surface, generating a color intensity artifact.

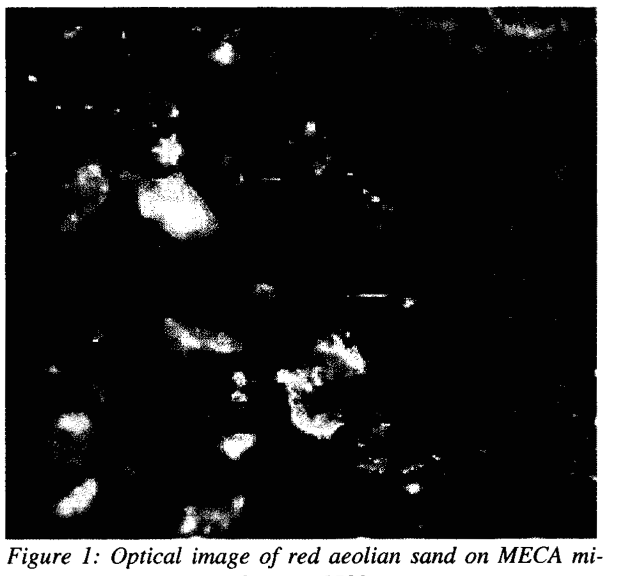

Figure 1: Optical image of red aeolian sand on MECA microscope stage. Width of view ~1500 microns.

The MECA microscope system also incorporates an atomic force microscope (AFM) for sample imaging. This instrument is mounted to the optical microscope for targeting purposes, and consists of a rastering stylus that senses the surface topography by operating in a tapping mode. Vertical position of the stylus (topographic information) is sensed by the piezoelectric cantilever arm on which the stylus is mounted. Nanoscale resolution is possible with this instrument. Its function for MECA is to quantitatively characterize the size and shape of dust grain populations, and to image the surface texture of larger grains. It is also intended for measuring scratches and mineral streaks produced by the microscope's scratch plate. Some of the AFM stylus tips were to be carbon nanotubes provided by NASA Ames Nanotechnology [2].

Figure 2 shows the red dune sand imaged with an AFM using nanotube tips --the system is comparable to that built for MECA. The image is that of the red coating and shows the material to be composed of an aggregate of granular components in the submicron size range. The origin of the coating is enigmatic. It appears to be absent from grain protrusions, suggesting that transport acts abrasively, as opposed to "plastering" the material onto the grains during mechanical contacts. The granularity of the coating is not particularly suggestive of chemical activity, although

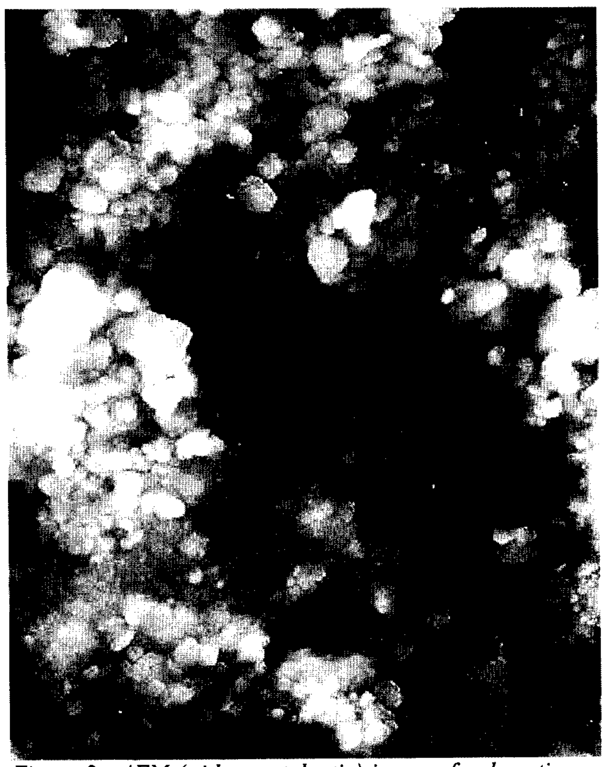

Figure 2: AFM (with nanotube tip) image of red coating on aeolian grains. Width of view ~3 microns.

other evidence [1] indicates a possible chemical origin, or at least, chemical modification. Conceivably, material is worn from mobile grains, but transport itself may have scavenged the granules in the form of electrostatically attracted dust associated with the dune environment (grains become electrostatically charged during transport). Percolation of seasonal water, or capillarity of dew moisture in the desert may be responsible for redistribution and chemical alteration of the coating --perhaps contributing to the ubiquitous distribution on the grains.

Figure 3 provides an AFM image of a quartz grain surface without red coating. Blocky surface textures occur at a scale of microns to tens of microns, and also at a submicron scale. Textures are suggestive of aeolian transport (these roughness elements give aeolian grains their frosted appearance), and compare well with the "upturned plates" texture considered indicative of quartz aeolian grains when they are imaged by SEM [3]. Water-transported grains tend to have much smoother surfaces owing to continuous dissolution.

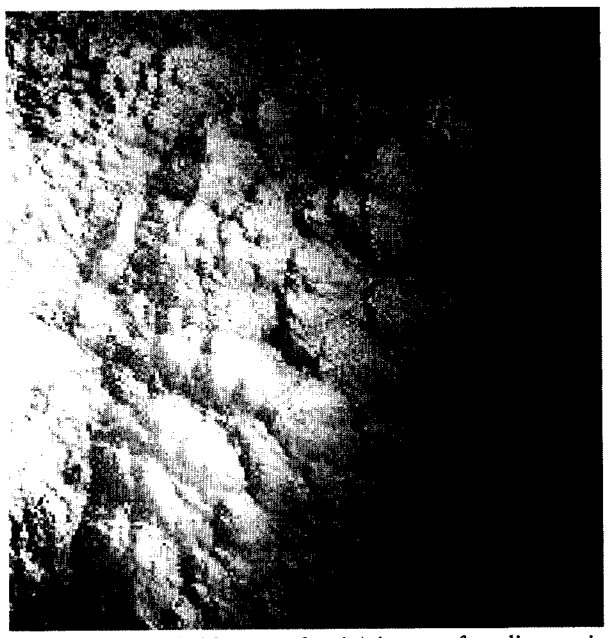

Figure 3: AFM (with nanotube tip) image of aeolian grain surface texture. Width of view ~3 microns.

AFM characterization of grain surface textures is in its infancy. The SEM database of textures is extremely extensive [4]; we therefore conducted SEM analyses to ground-truth our AFM data. The SEM provided identical images for the red coating, although machine problems prevented corroborative data for the uncoated, mechanically worn grain surface areas.

EDAX analysis of the red coating produced strong silicon, oxygen, and aluminum peaks, with two secondary iron peaks (also trace Zn, Mg, K, Ca, Ti). Both the color of the material and the EDAX data suggest hematite with aluminum replacement of the iron (a not uncommon process in deserts), and possibly clay or other mineral fractions intermixed. This is consistent with dust scavenging suggested above. The Al could also be derived from some of the feldspar grains in the sand population [see 1].

References: [1] Kuhlman, K. *et al.*, this volume, [2] Stevens, R. *et al.*, (2000) Nanotechnology 11, 1-5, [3] Krinsley, D. & Doornkamp, J. (1973) Atlas of Quartz Sand Surface Textures, Cambridge, [4] Marshall, J. (1987) Clastic Particles, VNR.